# $SO_2$ PROBLEMS

by

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## Introduction

The problem of emission of sulfur dioxide from the combustion of fossil fuels is not new, but it has received growing emphasis in recent years as one of the major targets in the overall attack on the pollution of our air. While there may be some disagreement as to the extent to which the presence of sulfur dioxide in the atmosphere constitutes a danger to life and property, there is no disagreement that its existence creates a problem.

Issuance of the Federal Air Quality Criteria for Sulfur Oxides in February of this year triggered a program whereby officials in certain designated air quality regions are required to meet a definite timetable for the development of control standards. Many cities and states have already been engaged in developing standards for the control of sulfur dioxide, having begun some years prior to the appearance of the Federal criteria.

This area of endeavor also has its problems. The development of standards, and plans for their implementation and enforcement, should be based upon a good understanding of the technological and economic factors involved in meeting the standards. Assessment of those factors is often difficult because of the lack of sufficient good data.

A significant amount of research is being conducted to solve a third type of problem. That is the development of technically and economically feasible methods for controlling sulfur dioxide emission at its source. It is in this area that the coal industry is vitally interested.

In spite of the acknowledged air pollution problems accompanying the use of coal, the ever-increasing demand for electrical energy alone will require its continued use for many decades. The challenge, therefore, is to develop means for controlling, or preventing, emission of pollutants from what will continue to be a major source of energy.

This paper reviews the status of current research aimed at providing a solution to the problem of sulfur dioxide emission from

coal-fired equipment. Emphasis is given to those control methods which appear to be approaching practical application.

Several approaches to the problem of sulfur dioxide emission appear, on the surface, to be rather elementary. One of these is the use of tall stacks, or multiple-flue stacks, to effect the release of flue gas at elevations where natural dispersion will reduce the concentration of sulfur dioxide which reaches ground level at any specific location. This concept is being employed quite widely in England, with results which are apparently acceptable at the present time. Several new power plants in the United States will have stacks 800 to 1,200 feet high.

Advancing technology in the area of high voltage transmission has led to the "mine-mouth" power plant concept. This locates the plant near the fuel source, away from the large urban areas which the plant generation serves. As a result, human population is much less affected by the plant effluent. But, the solution is not a complete one. Rural location of a power plant often places it in an area where major agricultural operations fall under the influence of stack emission. Thus, emission control is often equally necessary.

Current research includes the accumulation of data to evaluate the effect, upon ambient air quality, of high-level emission, or of emission in relatively isolated geographic locations.

An obvious, simple way to reduce sulfur dioxide emission is to reduce the amount of sulfur burned--use of a low-sulfur coal. Table 1 shows the sulfur content of utility coals. Ninety percent of these contain more than one percent sulfur, a level which is rapidly being incorporated into air pollution control legislation. Most of the reserves of low-sulfur coal lie west of the Mississippi River, which makes them economically unavailable to the large eastern energy market. Certain mid-west utilities indicate that the cost of one percent sulfur coal would be 50 to 100 percent higher than that of the higher sulfur coals currently being used.

TABLE I. SULFUR CONTENT OF UTILITY COALS

| Percent, Sulfur | Percent of Total | Percent, Cumulative |
|---|---|---|
| 0.4-1.0 | 10.4 | 10.4 |
| 1.1-1.6 | 12.8 | 23.2 |
| 1.7-2.2 | 20.4 | 43.6 |
| 2.3-2.8 | 14.6 | 58.2 |
| +2.8 | 41.8 | 100.0 |

An additional factor limiting the "simple" approach of substituting low-sulfur coal is the basic element of boiler design. Nature has established the general pattern among United States coals that those having a high sulfur content have a low ash fusion temperature, while low-sulfur coals tend to have high ash fusion temperatures. Boilers are designed for dry ash removal or for slag tap (wet-bottom) operation, depending upon the source of coal anticipated over the life of the unit. A shift to a low-sulfur coal and, therefore, to a high ash fusion coal, is often not possible in a boiler originally designed for wet-bottom operation.

## Desulfurization

If naturally low-sulfur coals are not readily available, then what are the possibilities of removing some of the sulfur before the coal is burned?

Sulfur in coal occurs in two main forms. A portion of it, the "organic" sulfur, is bound as an integral part of the coal molecule; the "pyritic," or mineral sulfur, exists as discrete particles in the coal mass. These particles vary widely in size, and in their distribution throughout the coal.

The ration of organic to pyritic sulfur in the United States coals can vary from 60:40 to 20:80. If the sulfur is predominantly pyritic, and if, during size reduction of the coal, it is of a size and distribution to allow it to be freed from the coal mass, then separation by gravity methods can be accomplished.

Early studies by Bituminous Coal Research, Inc., on a few selected high-pyrite coals, showed that an appreciable amount of the pyrite could be liberated and removed by gravity separation if the coal were reduced to a 60-mesh size or finer. Unfortunately, the coal size most compatible with pyrite removal was not a practical size for shipment.

It became apparent, therefore, that if pyrite removal is to be accomplished on those coals which are receptive to pretreatment, the process would have to be applied at the power plant. Accordingly, Bituminous Coal Research, Inc., is presently engaged in a pilot study on in-plant removal of pyritic sulfur utilizing characteristics of the pulverizer which accepts 1-1/2 inch coal, and delivers 200-mesh coal to the burners (Figure 1).

The research, jointly sponsored by 12 eastern utilities, incorporates a two-step process. First, the commercial power plant pulverizer has a built-in device for rejecting large pieces of pyrite-rich coal--the so-called "tramp iron chute." Initial study involves optimization of pulverizer performance, seeking a maximum reject of pyrite with a minimum loss of good coal.

The second phase of the research deals with the removal of pyrite from the intermediate size coal which recycles inside the pulverizer.

# Pyrite Removal

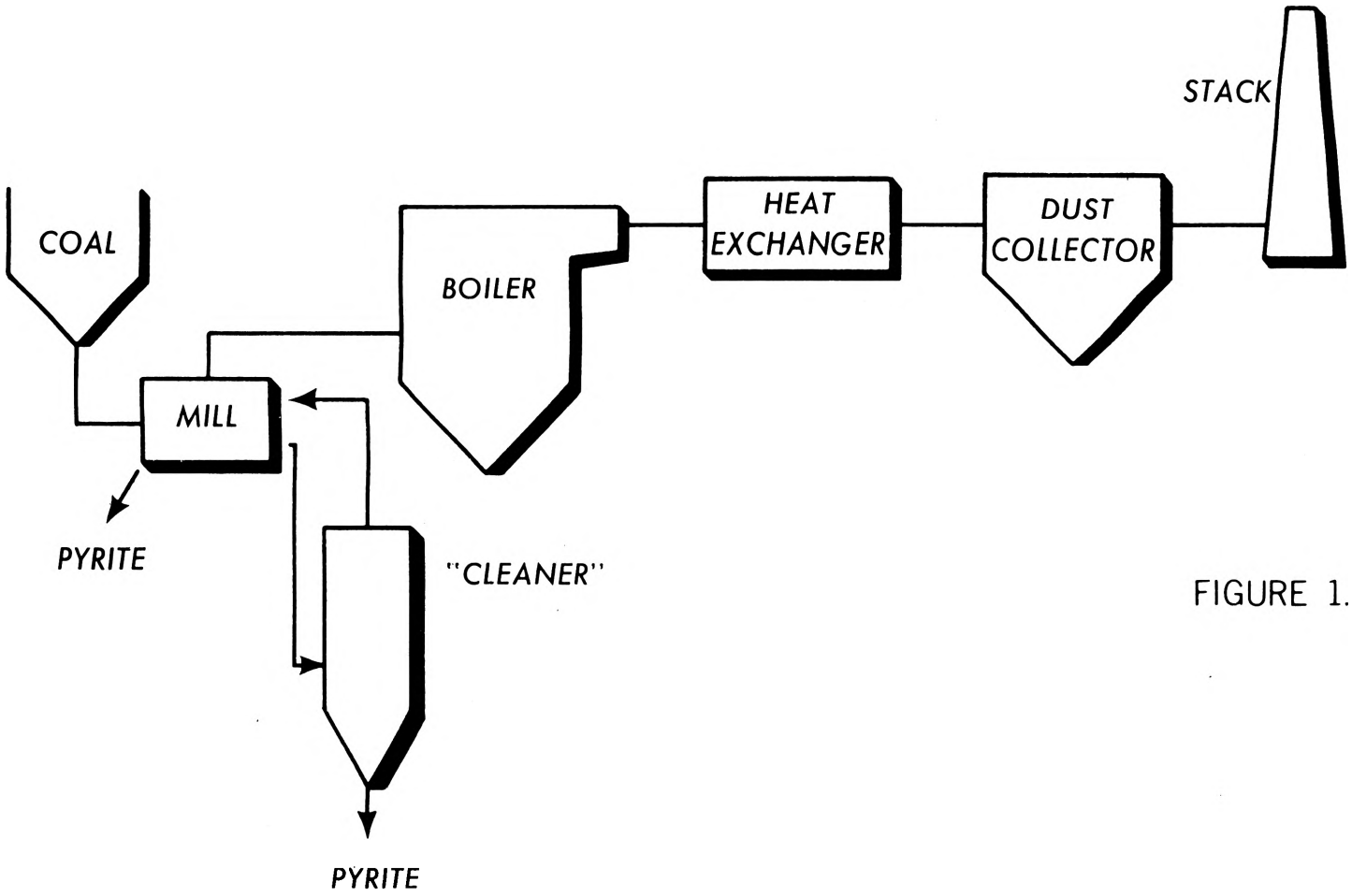


FIGURE 1.

A portion of this recycle load is gravity-cleaned externally and the clean, pyrite-free coal is returned to the pulverizer for further reduction in size.

The process will result in the rejection of a pyrite-rich fraction, with some loss of good coal which would have otherwise been burned. Additional research by others, much of which is under sponsorship of the Public Health Service, is directed toward the ultimate utilization of the pyrite-rich coal fraction. Successful utilization can favorably affect the economic of the pyrite removal process.

Still other research activity is aimed at determining how widely applicable pyrite-removal methods may be. Studies of sulfur distribution in commercial utility coals, and of the effect on pyrite removal of different cleaning methods, are a part of the research.

A recent paper by R. D. Saltsman, "Facing Up to the Sulfur Content of Coal," presented at the ASME Fuels Division Industrial Fuels Conference in St. Louis, described the coal preparation studies currently under investigation at Bituminous Coal Research, Inc. The multiphase program includes studies of the cleanability of various high-pyrite coals by conventional cleaning methods, and characterization of the pyrite-rich fraction which results from this treatment.

## Sulfur Dioxide Removal from Flue Gas

Lacking the ability to obtain, or use, low-sulfur coal, the next approach is the removal, or partial removal, of sulfur dioxide from the products of combustion before they are discharged into the atmosphere. Many approaches can be taken, and each is receiving a great amount of attention. Two general categories are being studied:

1. Additives
2. Flue Gas Processing

## Additives

Perhaps the least complex system is the introduction into the flue gas of an additive that will unite chemically with sulfur dioxide to form a solid compound (Figure 2). The compound thus formed can then be removed from the flue gas with conventional dust collection equipment. The use of finely-pulverized limestone or dolomite for this purpose is undergoing extensive study.

Early work by Wickert in Germany indicated that as much as 90 percent of the sulfur dioxide in flue gas could be removed by combining it with dolomite dust injected into the combustion unit. Subsequent work by others resulted in widely varying degrees of success.

# Chemical Additive

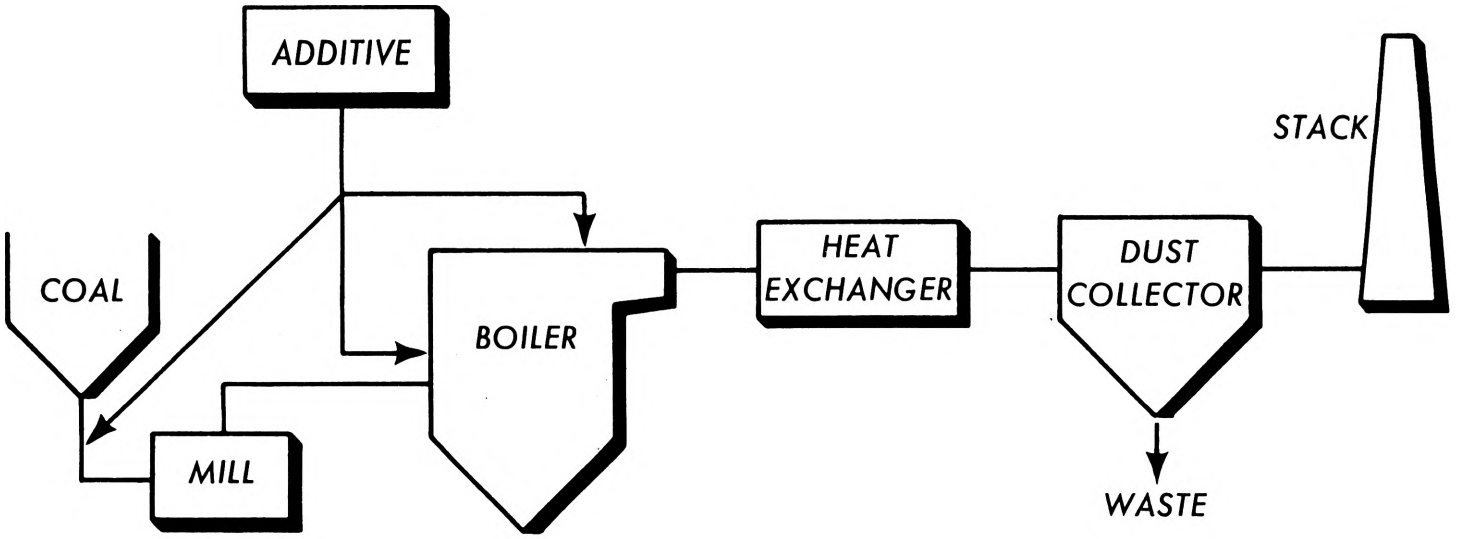


FIGURE 2.

Because of the potential of the method for partial or intermittent control of sulfur dioxide emission, a broad program of research is underway. The Public Health Service is sponsoring a multi-million dollar program of research in areas extending from basic thermodynamic studies of the limestone-sulfur dioxide reactions to full-scale demonstration of the method.

The use of additives such as limestone or dolomite is not without its problems. The choice of the location and method for introducing the additive into the flue gas is influenced by the need to get optimum reaction between the solid and the gaseous sulfur dioxide. The amount of additive required can, in some cases, be equal in weight to the ash content of the coal. The additional solid material in the flue gas must be efficiently removed by dust collection equipment, and its disposal must not create another pollution problem. Solutions to these problems are a part of the current research effort.

A full-scale test of a limestone additive system will be conducted late this summer on a boiler at TVA's Shawnee Station, Paducah, Kentucky. Additive testing on smaller-scale equipment is being conducted elsewhere. The city of Chicago, in cooperation with Midwest Coal Producers, has tested several additives on a multiple-retort underfeed stoker. In St. Louis, the Chevrolet Division of General Motors has been conducting additive tests on two industrial-size boilers. Peabody Coal Company, under contract with the Public Health Service, is testing additives on a pilot chain grate stoker.

Indications are that while emission of sulfur dioxide may not be reduced to the 90 percent level suggested by Wickert, some 30 to 40 percent is possible by the use of a limestone or dolomite additive system. While removal efficiency is not as good as that expected from the more complex systems to be described later, the method may be useful in specific instances. Where the fuel sulfur content is not extremely high, or where partial removal of sulfur dioxide is sufficient to meet required ambient air conditions, the use of additives may be the most practical approach.

Further, the use of additives may be the best solution for operators of commercial and industrial boilers. These units are not normally of sufficient size to accommodate most of the more complex flue gas processing systems.

The alkalized alumina process, under study by the U.S. Bureau of Mines at the Bruceton, Pennsylvania, experimental station, could be considered a variation of a dry additive system. Instead of using the boiler as the "reactor," the Bureau's process picks up flue gas at about 600 F and passes it through an absorber where it contacts entrained solid alkalized alumina. Sulfur dioxide is combined as a sulfate on the sorbent, which is then removed mechanically for regeneration and recycle. Regeneration of the sorbent releases hydrogen sulfide which is converted to elemental sulfur.

Current effort is being concentrated on improving the physical characteristics of the alkalized alumina. The relatively high cost of the synthetic sorbent requires that material loss in the system be kept to a minimum.

## Additive Plus Wet-Scrubbing

Scrubbing of flue gases with alkaline solutions prepared from materials such as calcine limestone or dolomite is a well-demonstrated method for removing sulfur dioxide (Figure 3). Wisconsin Electric Power Company and Combustion Engineering have both investigated the combination of dolomite or limestone injection with wet-scrubbing.

Additive is injected into the furnace of a boiler where it is converted to calcium and magnesium oxides by heat. The oxides carry through the system with the flue gas to a turbulent contact absorber where, with water, they form a dilute slurry of alkaline hydroxides. Sulfur dioxide reacts both with the oxides suspended in the gas, and with the hydroxide formed in the scrubber. The combined operation has been reported to remove in excess of 95 percent of the sulfur dioxide.

The wet-scrubbing process has the added advantage of removing solids from the flue gas. The problem of the increased dust burden is, therefore, not as critical as it is when additive injection alone is used. On the other hand, the flue gas leaves the scrubber saturated at about 120 F. In all probability, some degree of reheat will be required to assure satisfactory dispersion of the scrubbed gas.

Combustion Engineering is testing an additive injection and wet-scrubbing system in Union Electric's Meramec Station. Kansas Power and Light has installed the Combustion Engineering process on an existing 125-megawatt boiler at the Lawrence Station, and is planning a second unit on a new 430-megawatt boiler being erected there. These installations will afford the opportunity to assess the feasibility of the process on a commercial scale.

Disposal of the fly ash-alkaline earth sludge is a problem that must be resolved. Recently, Combustion Engineering revealed that they are investigating the conversion of the sludge into a usable produce such as "cement clinker" or light weight aggregate. The process would release sulfur dioxide for sulfuric acid production.

## Flue Gas Processing

In some respects, flue gas processing methods (Figure 4) are similar to the additive approach with wet-scrubbing, described above. However, instead of using a low-cost material, such as limestone, and producing a non-saleable waste product, some of these systems employ relatively high-cost chemicsl re-agents. Regeneration of the reagent

# Wet Scrubber/Collector

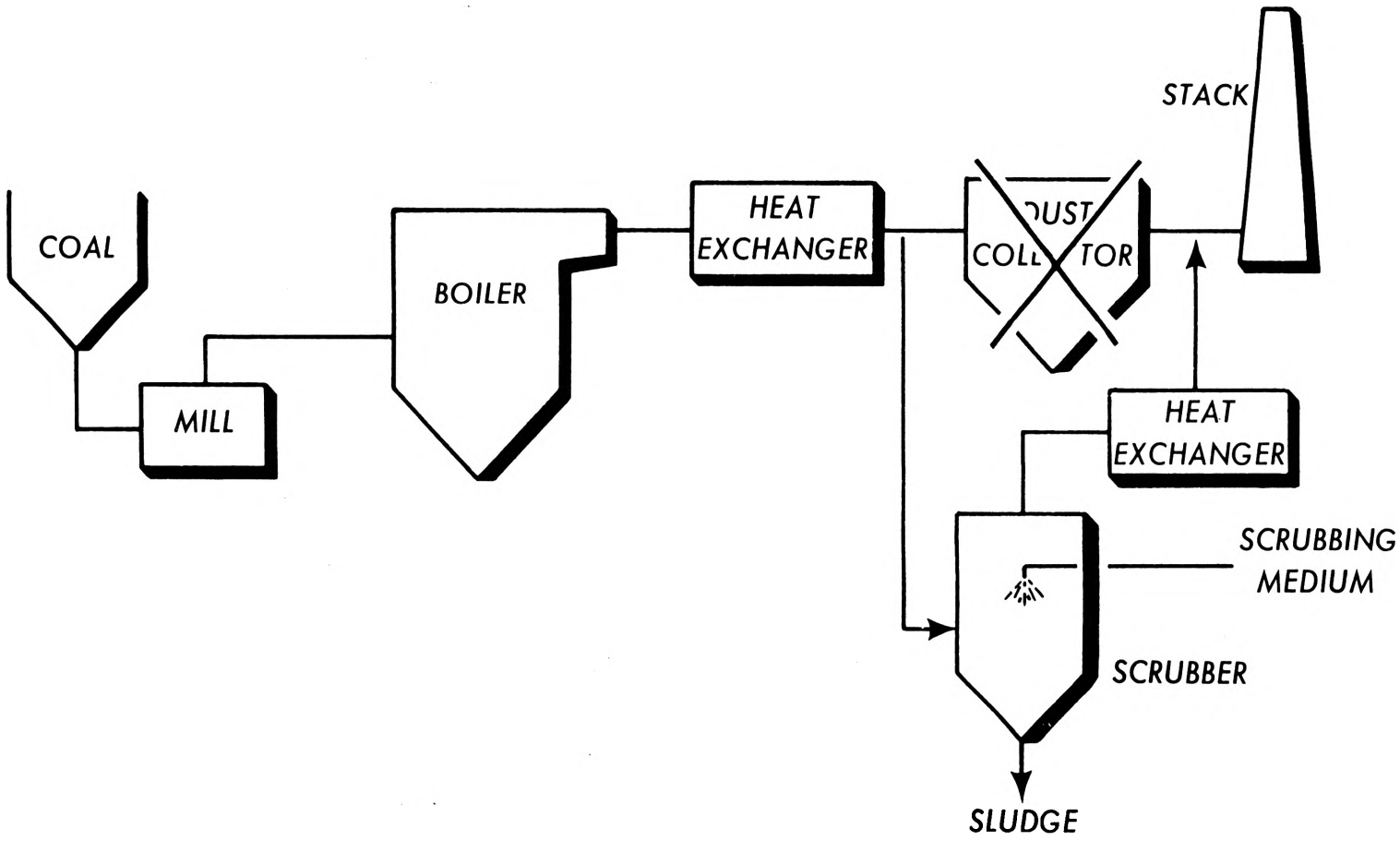


FIGURE 3.

# Flue Gas Processing

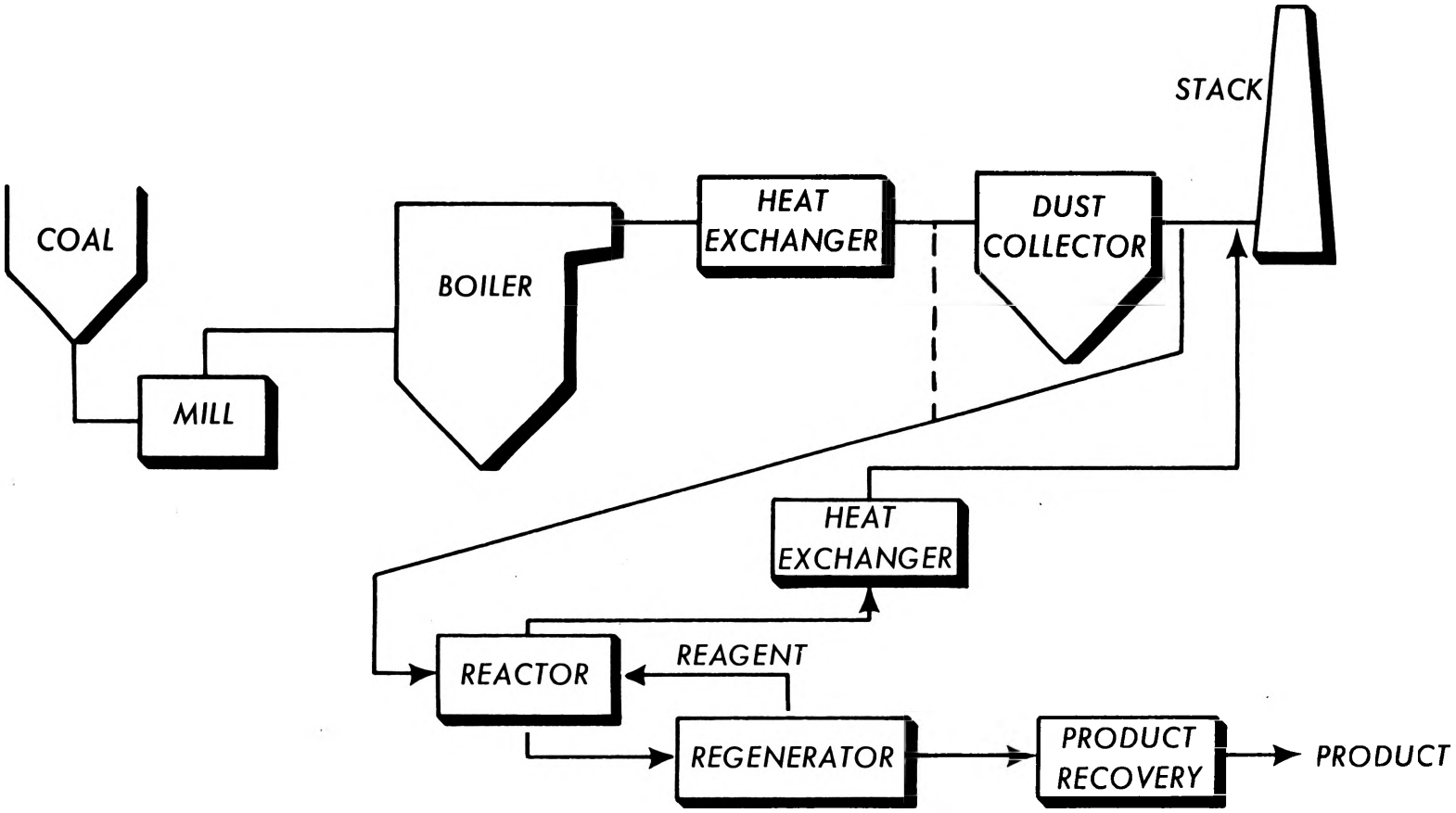


FIGURE 4.

becomes an important part of the process, and production of sulfur in a saleable form is required to offset the higher cost of the overall operation.

After extensive pilot testing, Wellman-Lord, Inc., a subsidiary of Bechtel Corporation, has installed a demonstration plant at the Crane Station, Baltimore Gas and Electric Company. The Wellman-Lord process scrubs flue gas with a potassium sulfite solution, the regeneration of which results in the production of liquid sulfur dioxide. Recent reports indicate that the demonstration plant is confirming data previously obtained on the pilot plant.

Chemical Construction Corporation, drawing on its experience in the use of wet-scrubbing techniques for removing particulates from high-volume gas streams, is engaged in the development of the use of aqueous solutions to simultaneously remove sulfur dioxide. Chemico's somewhat unique approach is the concept of a centralized plant for processing spent reagent. In theory, the central plant would receive spent reagent from "satellite" gas-scrubbing installations, regenerate the reagent, producing elemental sulfur as a product, and return fresh reagent to the scrubber users. This concept would benefit operators of smaller combustion equipment, whose installations are not sufficiently large to make a complete closed-cycle system economically feasible.

North American Rockwell Corporation, Atomics International Division, is under contract with the National Air Pollution Control Administration to develop a hot scrubbing process, using molten carbonate salts as the scrubbing medium. This project is rapidly approaching the pilot stage.

These are a few of the gas scrubbing processes that are progressing to the stage where technical, engineering, and economic feasibility can be established. NAPCA is funding, or negotiating, contracts for research in all phases of gas scrubbing, ranging from fundamental studies to support of pilot tests. Important questions in the evaluation of such systems include:

1. Can they be employed as "add-on" systems to existing boiler installations, or does their best application require that they be an integral part of the combustion system design?

2. How much does the economic use of the systems depend upon recovery of the sulfur as a marketable product?

3. Can the problem of a wet, cool plume, which results from many gas scrubbing processes, be solved satisfactorily?

There are some obvious advantages to the use of gas-scrubbing techniques for sulfur dioxide removal. The efficiency of removal is quite high. The standard hardware can be adapted. In most systems, fly

ash removal is simultaneous, and in many, the presence of flay ash in the scrubbing medium has only a minor effect on subsequent processing for sulfur recovery and reagent recycle.

Still another approach to removal of sulfur dioxide from flue gas is to convert it to another form before removal. The Monsanto process (Figure 5), which catalytically oxidizes sulfur dioxide to sulfur trioxide and scrubs the latter from the gas with cool sulfuric acid in a packed-bed absorption tower, is an example of this category of processes. The Monsanto pilot plant at Metropolitan Edison"s Portland (Pa.) station has been operating since late last summer. Monsanto reports that the plant has accumulated some 6500 hours of satisfactory operation, and has produced about 1000 tons of sulfuric acid, all of which has been sold. The plant is providing detailed engineering and operating data needed for scale-up to commercial size. While a commercial installation has not yet been announced, it is probable that a demonstration unit will be a reality before too long. Because the process requires some special conditions, such as high-termperature fly ash removal and catalyst operation at about 900 F, it is best suited for application in new, totally integrated combustion systems.

## Other Research

At the outset, it was pointed out that the processes to be discussed were those whose development appears to be approaching commercial realization. By no means do these processes constitute the only possible solutions to the problem of control of sulfur dioxide emission.

At the close of calendar 1968, the National Air Pollution Control Administration had 132 active contracts in effect, totaling $15.5 million. A third of these contracts, and nearly half the funds, involved research on sulfur dioxide control. Many of the contracts represent cooperative funding of work being conducted by industrial organizations.

The total effort covers a broad field of research, from paper studies and bench experiments to the design of prototype plants. Included among the concepts under study are such subjects as direct conversion of sulfur dioxide to elemental sulfur, the use of organic liquids or solids as sorbent agents, fluidized-bed contactors, fabric filters for simultaneous collection of fly ash and sulfur dioxide from the other flue gas components. Technical ideas, chemical reactions, and process hardware are available in abundance. The task is to combine these elements into a process that can be applied to the solution of the problem.

## Conclusion

With all the research activity by various organizations, it is probable that an economically attractive approach for the reduction of

# Catalytic Oxidation

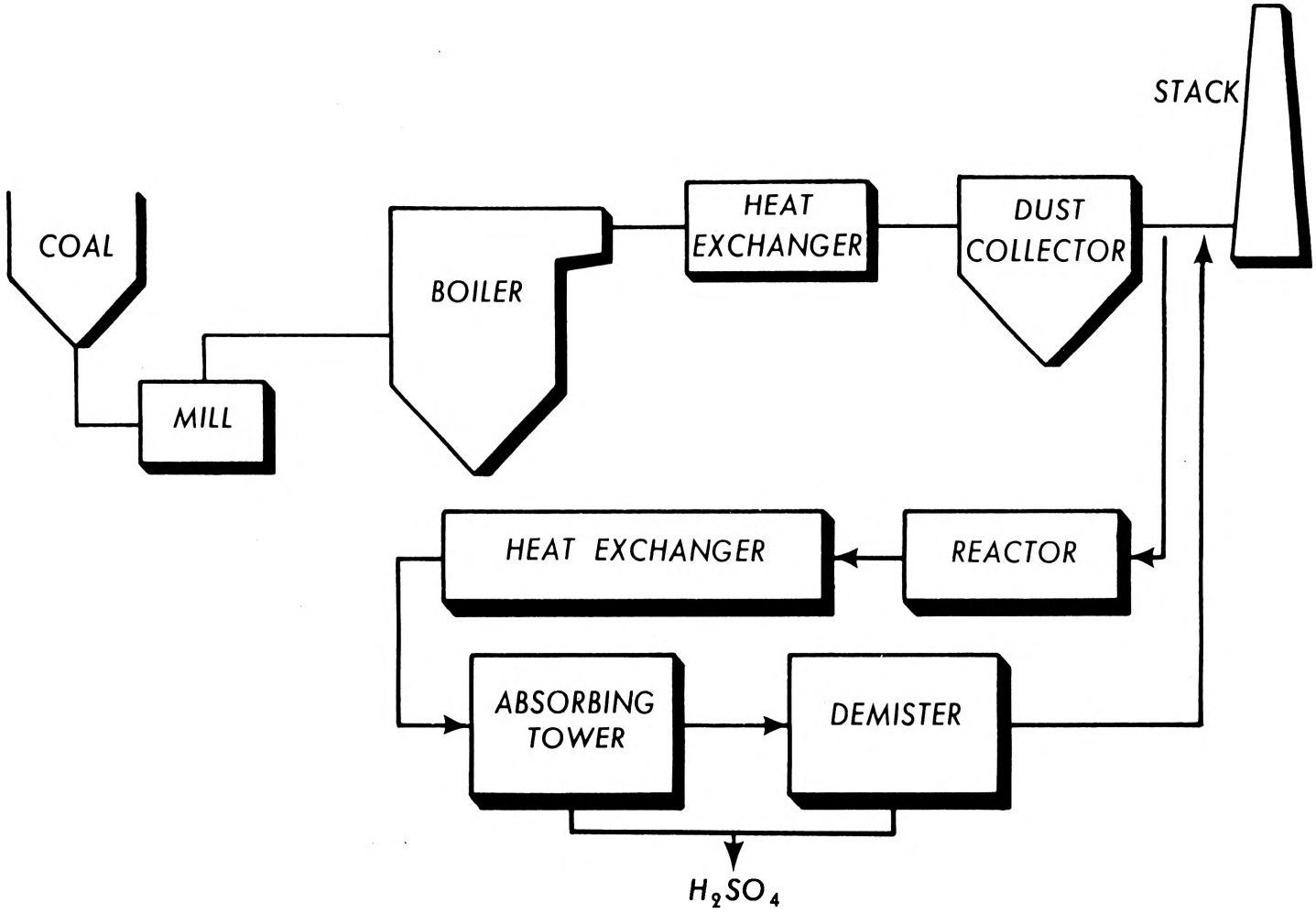


FIGURE 5.

sulfur dioxide emission will be available in the next two to three years. First-generation processes, such as those being tested by Combustion Engineering, Monsanto, Wellman-Lord, etc., might be available in less than two years, depending upon the success achieved in the research which is now underway.

Large prototype experience on many approaches is anticipated within the next several years. This should provide the engineering know-how and detailed economics that will clearly establish the commerical feasibility of the processes.

## COMMENTS

QUESTION: I'd like to ask Mr. Diehl a question within the realm of economics, after all the public is going to have to pay for this. What are we going to have to pay for this?

ANSWER: There are economics being published right now. If you look at them closely you will find the economics pretty clearly relate back to economics of the Bureau of Mines put out about ten years ago. When these processes were on paper and were not really as far advanced as they are now. I think I could give you a range and it is not going to come cheap. The problem with economics is this floating target, how much can you get for a sulfur product? When sulfur sells for $45 a ton then I can operate one of these control processes that will cost a net operating cost to the power plant of perhaps 50¢ a ton of coal. But it the sulfur price does not remain at $45 a ton and drops to half that then may operating cost is going to rise at the same time. So I think what we have to say is that the cheapest process is probably an additive process. According to some studies done not too long ago by T.V.A. this can be accomplished for a relatively low capital investment. I am sorry I don't know this number but at a cost of somewhere around 65¢ a ton of coal operating cost added to the equivalent of this cost. This range then moves right on to $1.75 and in one case economics look like $2.10 a ton of coal equivalent for operating cost.

Although the uranium people don't scare us we do have this problem of trying to get a process operating which will not really make the cost of coal utilization that much higher. We in the industry look at it as how much a ton of coal it is going to cost. Capital cost can run as high as $10 installed killowatts to something over $20 installed killowatts. This is on a power plant where the cost of constructing the power plant is about a $110 a killowatt so you can see that you are talking of appreciable capital cost. The operating cost will range anywhere from about 65¢ a ton of coal to in the area of $2.00 a ton of coal.

## ABSTRACT

# AIR POLLUTION CONTROL IN THE CEMENT INDUSTRY

by

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Portland cement manufacturing plants - both old and new - located in congested and sparsely populated areas of the country have, for many years, installed the most modern and efficient emission control available at the time.

The process of selecting, proportioning, grinding, heating, cooling, and grinding again of materials sub-micron in size makes close emission control essential.

The technical difficulties of adapting presently available emission control devices to a complex manufacturing process and controlling emissions within the limits of recently enacted or pending air pollution control regulations are great in magnitude and cost.

Neglect of any one of a multitude of design parameters, or inadequate, improper design of control devices can make a continuous high level operating efficiency essentially impossible to attain.

In some instances, increased technology may permit further emission control improvements - at high cost. Proper emphasis should now be placed on the "technically feasible, economically reasonable, practically enforceable" air pollution control regulation, and logical priorities for achieving the same.

Only through the cooperative efforts of the control agency, the public and industry will we be able to achieve the goals of desirable air quality levels.

# AIR POLLUTION CONTROL IN THE CEMENT INDUSTRY

In discussing air pollution control within the cement industry, we will touch upon the following:

A. Geographic Concentration of Manufacturing Plants

B. Manufacturing Process and Emission Control

C. Emission Control Costs

D. Technical and Legislative Control Difficulties

A. Geographic Concentration of Manufacturing Plants (V-1)

This slide illustrates the geographic location of producing plants. The concentration shown in some areas is a result of many influencing factors such as raw material availability, marketing potential, transportation, availability of utilities, etc.

Plants are located in the heart of major metropolitan areas as well as sparsely populated areas.

B. Manufacturing Process and Emission Sources (V-2) (not included in paper)

Reduced to its simplest terms, the process for manufacturing Portland Cement has been defined as "Select some raw materials, proportion them, grind, heat, cool and grind again."

Manufacturing can be by either the wet or dry process.

This is an aerial view of the General Portland Cement Company wet process plant located near Miami in Dade County, Florida. The appearance of a dry process plant from this view would be essentially the same.

(V-3)

Drilling is an emission source generally occurring deep within the plant and quarry property, thereby, virtually eliminating any effect off plant property. Where collection is required, drill dusting is controllable by means of a small cyclone or bag-type arrestor.

Emulsion type spraying may be employed to reduce emissions created as raw materials are dumped into the primary crusher. Excessive moisture

(NOTE: V = Visual)

V-1

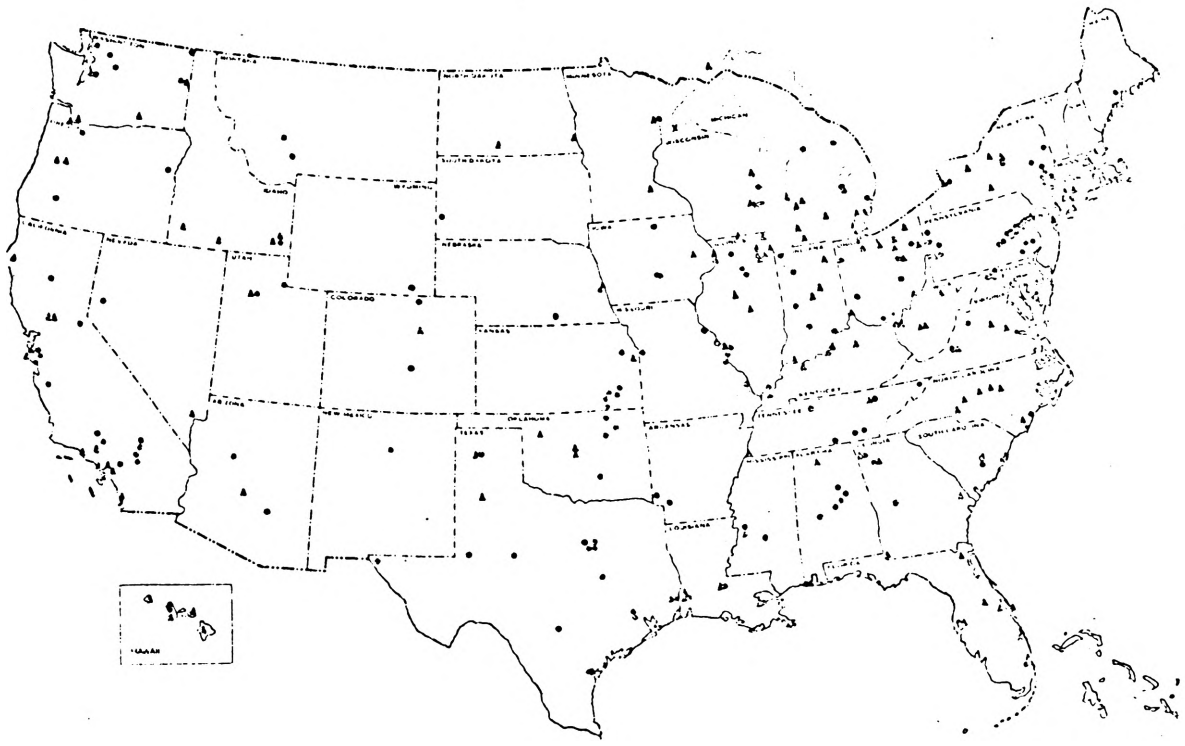
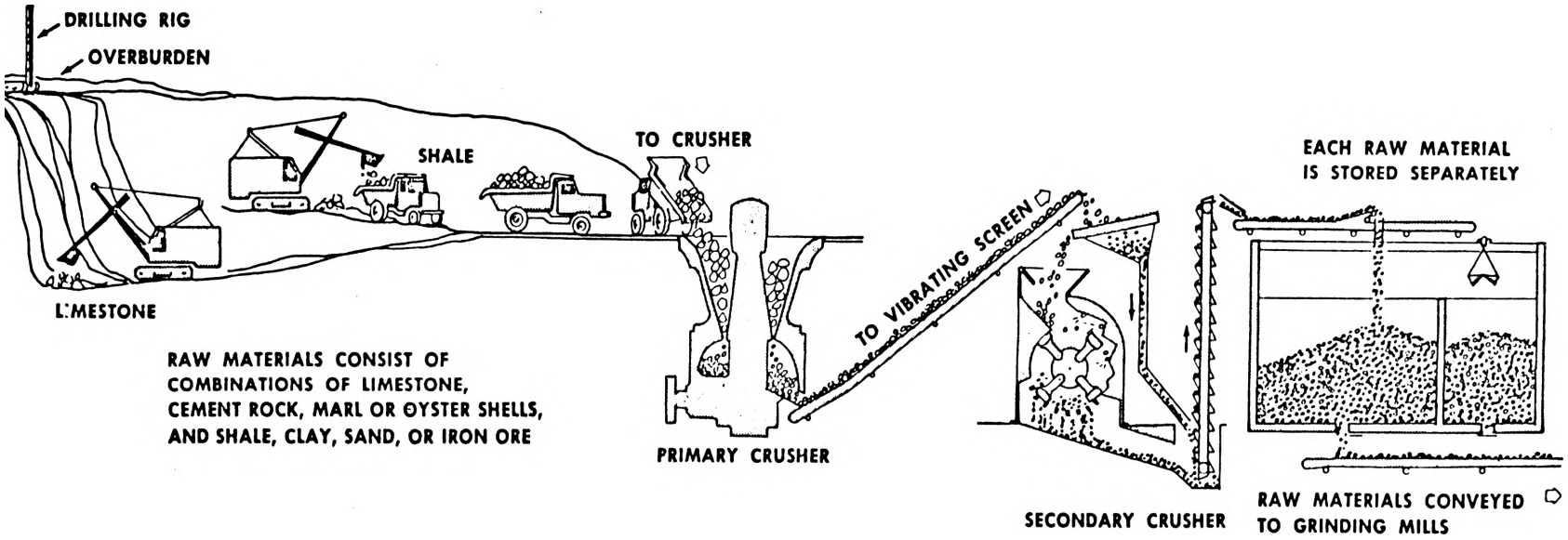


Figure 2. Portland cement plant locations in the United States (1965).




1. Stone is first reduced to 5-in. size, then ¾ in., and stored

addition must be controlled, however.

Primary and secondary crushing and material conveyor transfer point emissions are usually controlled by means of cyclones or low temperature bag-type collectors.

Crushed materials, reduced to approximately 3/4" size, are stored in various ways preceding the raw grinding phase.

The method of emission control may vary depending upon the storage method used. Raw material characteristics oftentimes dictate storage and handling methods.

Grinding and Blending (V-4)

1) Dry Process - Stored, dried materials are accurately proportioned and conveyed to the raw mill grinding system which generally consists of a mill in closed circuit with an air separator for product classification. Partial drying may be accomplished in the mill circuit by supplemental heat. Materials in transit through the system are conveyed typically by means of screw conveyors, elevators and air slide equipment.

Raw grinding involves the process of reducing the size of the proportioned raw materials to approximately 85% - 90% passing through a 200 mesh sieve. The clear opening of such a sieve is approximately 0.0029 inches.

Close emission control is therefore essential. Emission control is normally accomplished by low temperature bag-type collectors - sometimes in combination with scalping cyclones.

2) Wet Process - Feed materials for the wet raw grinding circuit may involve materials stored relatively dry and, in the case of previously processed clay, in "slip" form at perhaps 60% - 70% moisture content.

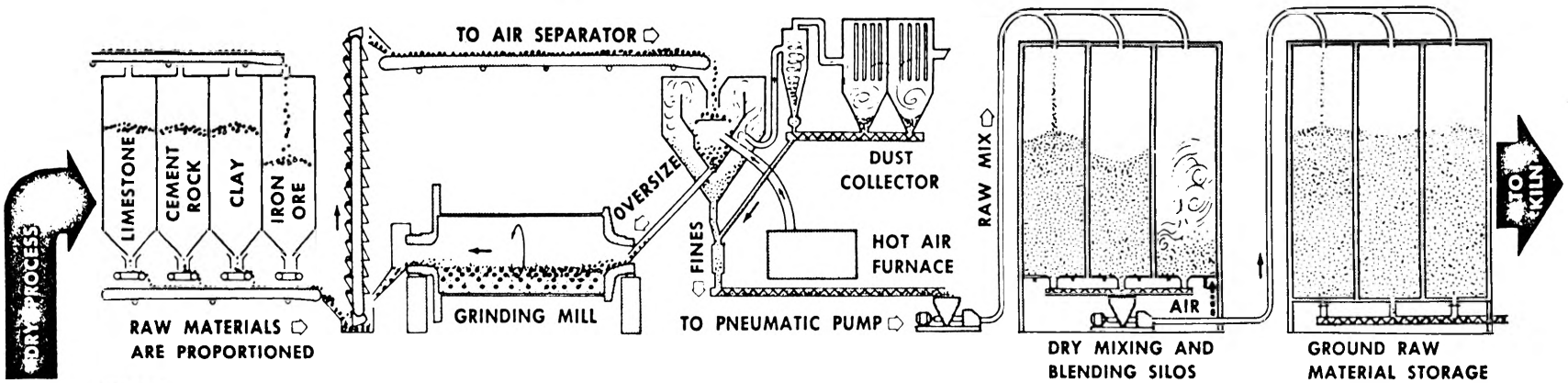
Emissions from the transfer of dry feed components to the mill are normally controlled by low temperature bag-type collectors.

The grinding system generally consists of a mill in closed circuit with some type screening device for classification.

Wet process raw grinding by its general nature is not a dust emission source.

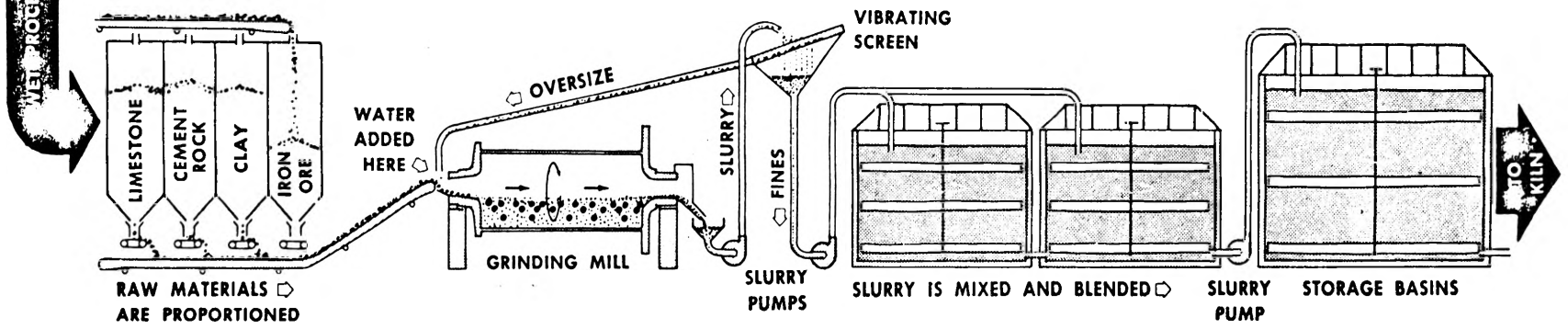
Slurried materials leaving the circuit are generally conveyed by pump to kiln feed blending and storage facilities.

(V-4)




OR

2 Raw materials are ground to powder and blended, or




2 Raw materials are ground, mixed with water to form slurry, and blended

Clinker Burning (V-5)

The heart of the manufacturing process is the clinker burning operation where raw mix is changed into clinker.

The system normally consists of a rotating kiln varying in size to as large as 25 feet in diameter by 760 feet in length. Such a kiln may process over 7,000 tons per day or over 600,000 pounds per hour of feed on a dry basis.

Fuel and combustion air are introduced at the discharge end of the kiln and dust laden exit gases are withdrawn from the kiln feed end by means of an induced draft fan.

Exit gases pass through a dust collecting device enroute to the stack.

Electrostatic precipitators and fiberglass filters, sometimes in combination with mechanical collectors, are normally employed.

Application of wet scrubbers is complicated by the cementitious properties of the kiln dust.

Cooled clinker is conveyed to storage with emissions normally controlled by low temperature bag-type collectors.

Finish Grinding (V-6)

The finish grind circuit is much the same as the dry raw grind system.

Mechanical scalpers and low temperature bag-type collectors are most frequently used, but electrostatic precipitators have been installed on occasion.

Control of emissions from conveying finished cement to packing and loading facilities is generally accomplished by the use of low temperature bag-type collectors.

Plant Equipment Views (V-7 thru V-12) (not included in paper)

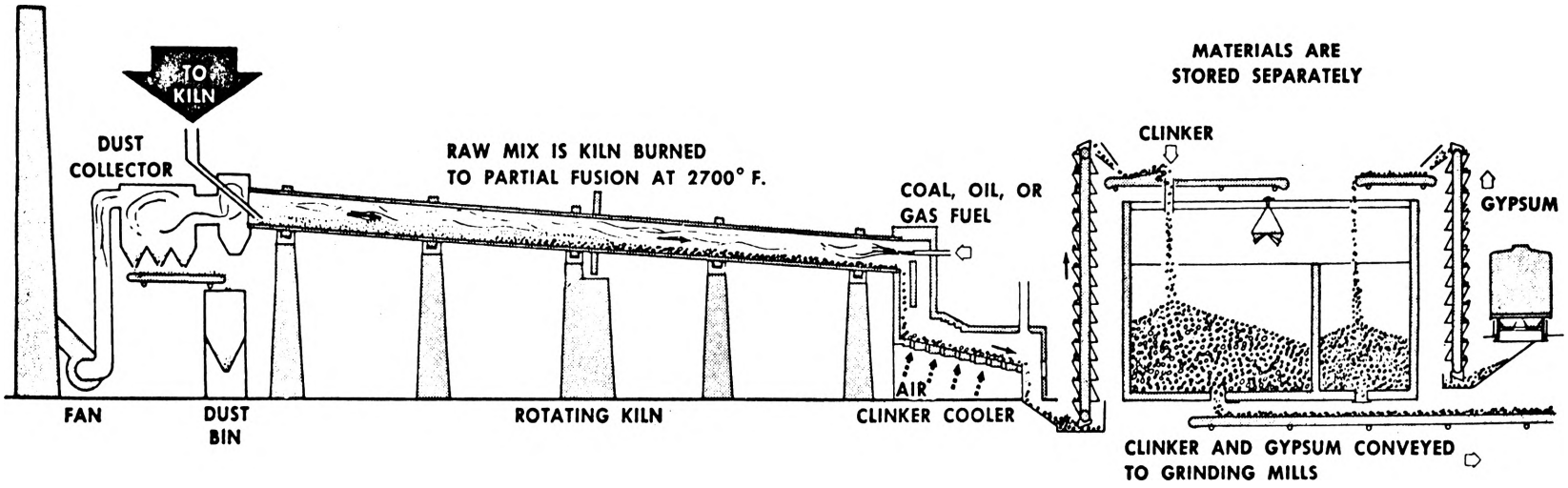
This group of actual plant view slides further illustrates the process equipment involved.

C. Emission Control Costs

It is difficult to generalize on emission control costs because of the limited amount of data presently available.

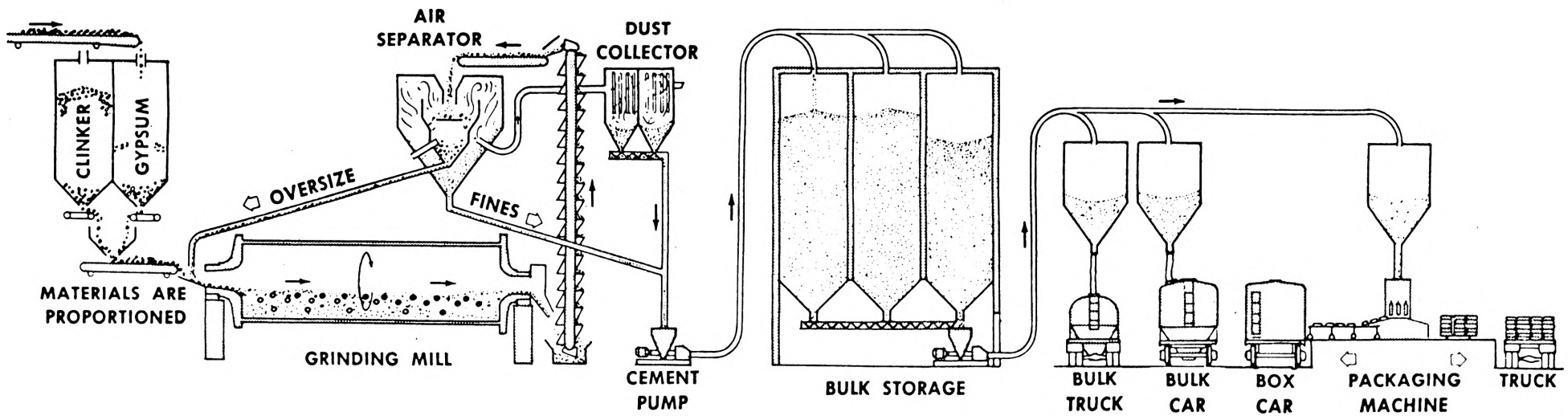
Accounting methods have, in many cases, incorporated emission control cost as part of larger account items.

(V-5)




**3** **Burning changes raw mix chemically into cement clinker**

(V-6)




**4** Clinker with gypsum added is ground into portland cement and shipped

Sufficient data have been accumulated, however, to reflect some specific installation costs. For example, one plant with an annual capacity of 2,700,000 barrels reports a total air pollution control investment of $2,500,000, or approximately $0.97 per barrel of plant capacity. Such an investment may represent approximately 10% of the total plant investment.

Companies have reported kiln dust collector "total installed costs" at 400-600% of the original equipment purchase cost.

The U. S. Department of Health, Education and Welfare document on "Control Techniques for Particulate Air Pollutants", N.A.P.C.A. Publication #AP-51, Table 6-3 shows an "extreme high" total installation cost for high voltage electrostatic precipitators at 400% of purchase cost - somewhat less than that frequently experienced in the cement industry. The "extreme high" for fabric filters is given at 400% - perhaps more in line with cement industry experience.

Table 6-5 of the H.E.W. publication gives the "high" annual maintenance costs for high voltage electrostatic precipitators at $0.03 per actual C.F.M. For 400,000 A.C.F.M., this would amount to $12,000 - $32,000 annual maintenance costs.

Figures 6-13 and 6-14 graphically indicate the purchase and installed costs of high voltage electrostatic precipitators.

The high efficiency curves on both graphs indicate for a 400,000 A.C.F.M. unit a $300,000 purchase cost and a $600,000 total installed cost. Applied to a cement kiln, such a unit would likely exceed a cost of $1,000,000.

(V-15)

Another cost of kiln emission control is that of dust return. Figure 6-26 of the H.E.W. Publication projects, for a hypothetical example, an economic break-even point of approximately 97% collection efficiency. In the case of cement kilns, the break-even point may require substantial or total discard of collected dust or water-leaching treatment which may create a secondary problem of water pollution control.

The Cement Environmental Matters Technical Subcommittee of the American Mining Congress has, for some time, been cooperating with the Economic Effects Research Division of N.A.P.C.A. in the development of a questionnaire intended to develop data from which expenditures incurred in reducing air pollutant emissions can be more accurately determined.

The completion of this study will provide more information of interest to all concerned with control of emissions from cement plant operations.

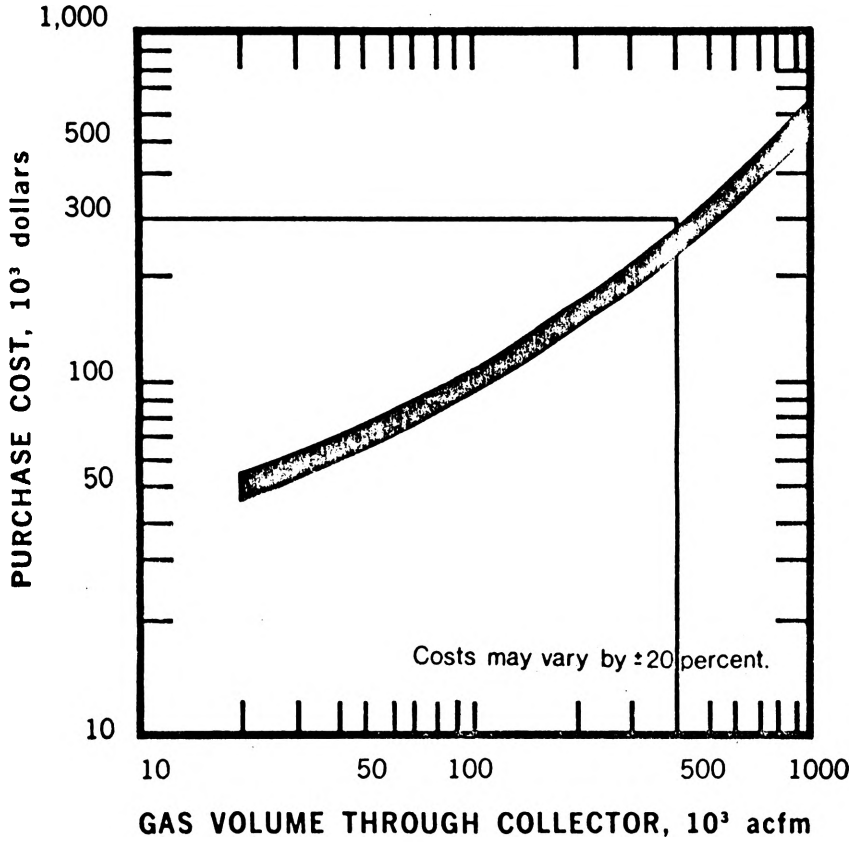



Figure 6-13. Purchase cost of high-voltage electrostatic precipitators.

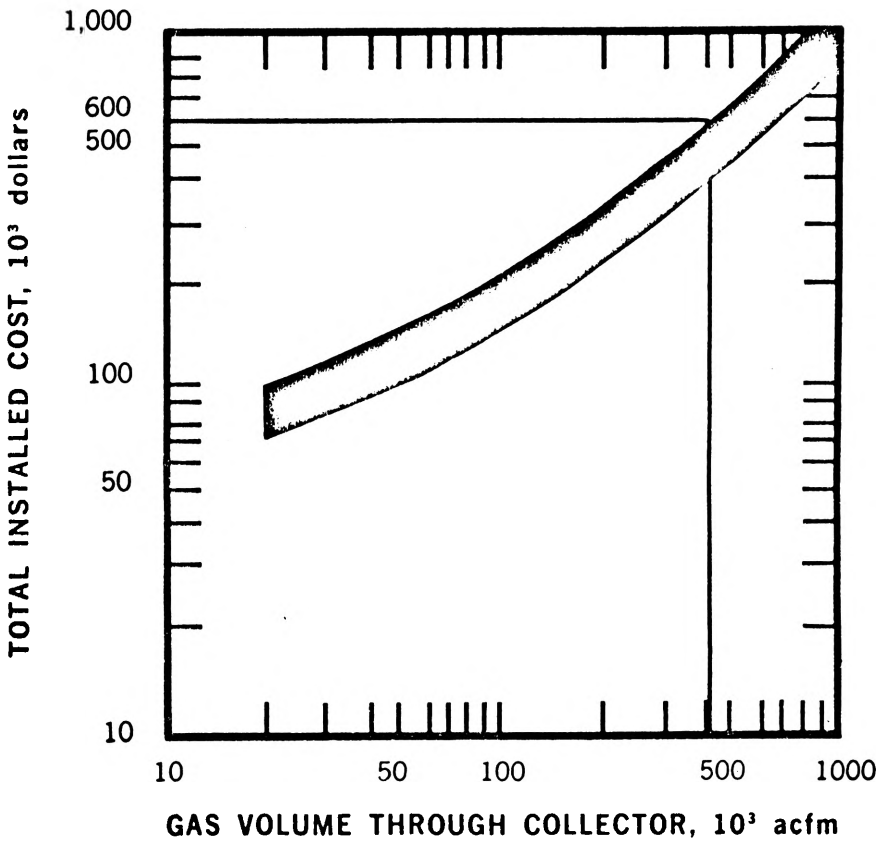
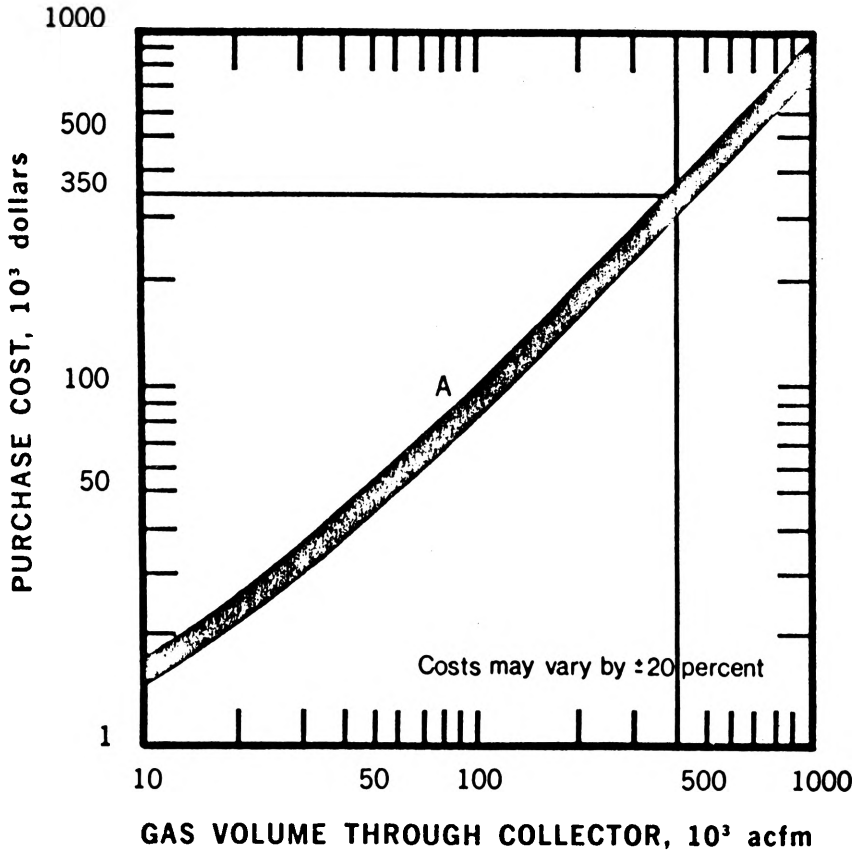
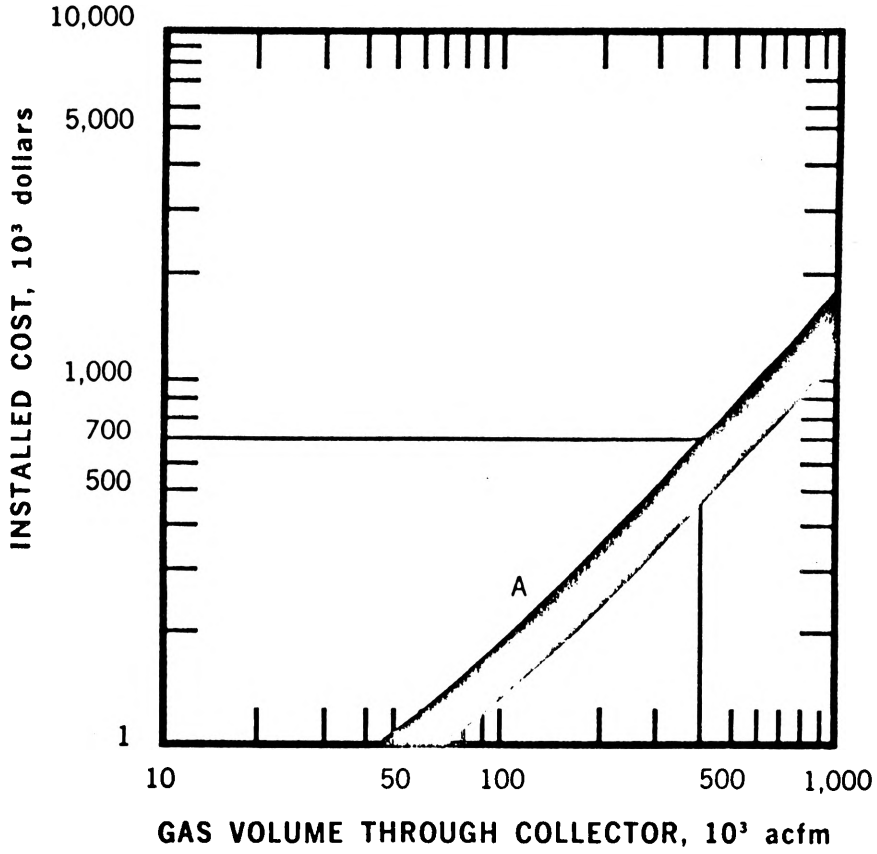



Figure 6-14. Installed cost of high-voltage electrostatic precipitators.




A — HIGH-TEMPERATURE SYNTHETICS, WOVEN AND FELT. CONTINUOUS AUTOMATIC CLEANING.

Figure 6-19. Purchase cost of fabric filters.




A — HIGH-TEMPERATURE SYNTHETICS, WOVEN AND FELT. CONTINUOUS AUTOMATIC CLEANING.

Figure 6-20. Installed cost of fabric filters.

(V-15)

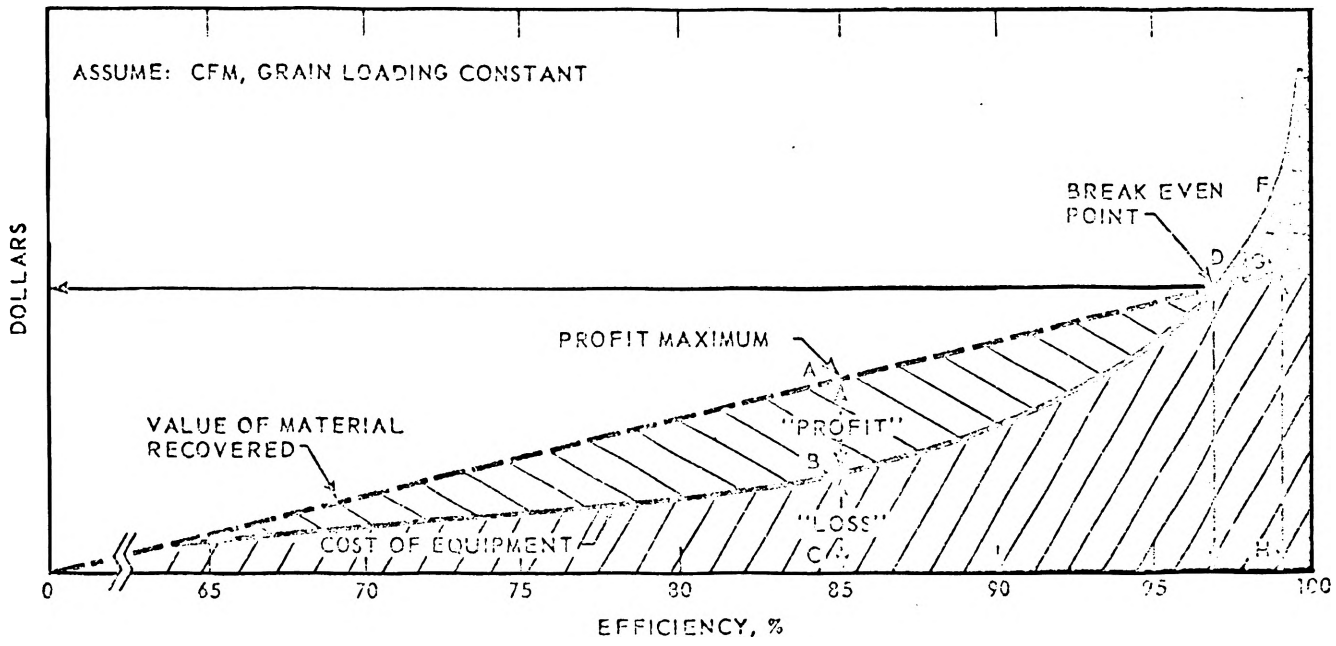



Figure 6-26. Theoretical effect of dust value on control cost.

(V-16)

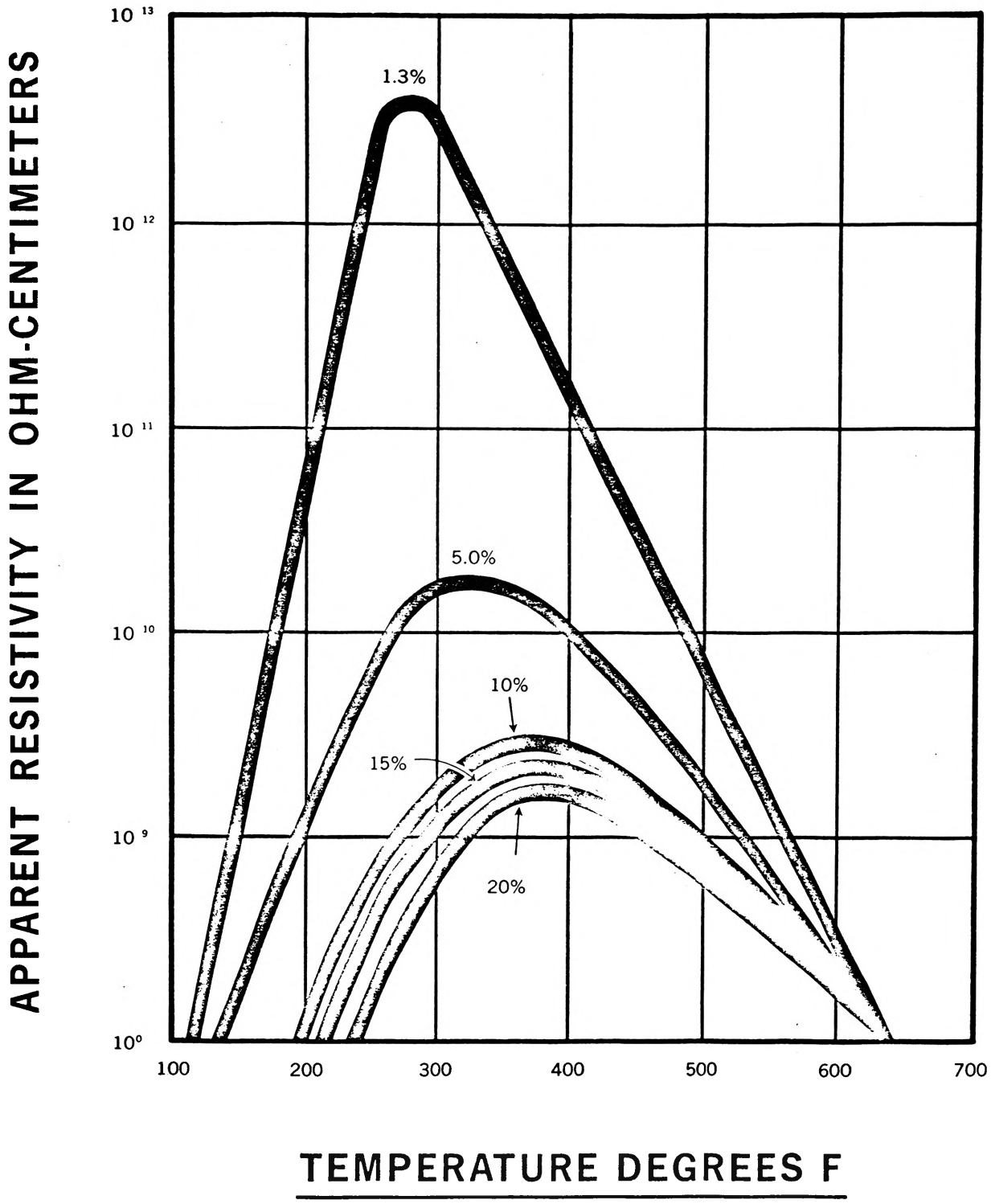



Fig. 6. Moisture and Temperature Effect on the Resistivity of a Cement Dust.

From Control of Dust Emission in Cement Plants,
R. J. PLASS, Mill Session Paper M-185
Portland Cement Association, Research and Development Division, 1966.

D. Technical and Legislative Control Difficulties

1) Technical - The problem of cement kiln exit gas dust emission control has been described as consisting of two phases. The first phase is the removal of particulates from the gas stream by forcing their accumulation on the collecting media.

In many cases, the collecting "first phase" is more easily accomplished than the second phase - getting the collected dust out of the emission control device.

Technical problems are further complicated by a third phase - dust disposal.

Long-established parameters essential to the proper design and application of precipitators and fabric filters are too numerous for discussion at this time.

Let us take a moment, however, to look at the problem of particulate resistivity which has become of increasing importance as we are faced with higher and higher operating efficiencies.

Resistivity - a measure of the difficulty with which a particle will take on electrical charge - is determined by the type particle involved and temperature and humidity of the exit gas stream.

Resistivity peaks often occur close to actual inlet gas temperatures of emission control devices.

Elevating gas temperatures to lower resistivity would increase fuel costs, gas volumes and precipitator sizes. Lowering gas temperature by infiltrating air tends to lower resistivity, but at the expense of increased gas volumes and precipitator size.

Resistivity reduction is generally accomplished by increasing the percent moisture in the exit gas stream through the use of high pressure atomizing water sprays. This has the multiple advantage of lowering gas temperature and volume, increasing gas moisture content, and lowering resistivity.

Any of the above methods involve substantial expense.

Neglect of any of a multitude of such design parameters, or inadequate, improper design can make a continuous high level operating efficiency essentially impossible to attain.

2) Legislative - Hastily conceived, illogical emission control regulations which are not "technically feasible, economically reasonable" or properly enforceable are equally perplexing when related to the technical problems previously mentioned.

Throughout the nation, there is an almost universal tendency to adopt the equivalent of the San Francisco Bay Area Process Weight Code and the Equivalent Opacity concept.

The differences in industrial processes leave the universal application of the process weight table and the equivalent opacity concept open to serious question.

The original process weight regulation concept was developed for application in March, 1949, to the metallurgical industries of Los Angeles County, California. The development is described in the November, 1949, issue of Industrial and Engineering Chemistry article on "Dust and Fume Standards".

The article describes how, for metallurgical industries, furnace process weight and stack losses were plotted graphically.

The average collecting efficiency required of small industrial units was approximately 80%; of large industrial plants, approximately 90%. Only the largest process unit having a 3% loss would be required to collect 98% of its stack discharge.

The maximum permissible emission of 40 pounds per hour was established at 60,000 pounds per hour of process weight under the Los Angeles code which was over three times the process weight of the largest industry involved.

The San Francisco Bay Area Process Weight Code is only slightly more lenient than the Los Angeles code.

It appears somewhat questionable to lift a rule that has been developed for one specific application and project it into an area with altogether different conditions.

For example, the 3% loss and 98% collecting efficiency applied to the "largest" metallurgical unit as described in the "Dust and Fume Standards" for Los Angeles County compares to approximately 18% loss and 99.8-99.9% collecting efficiency for pyro-processing industries such as cement manufacturing.

Careful consideration given to the development of the original Los Angeles process weight regulation logically must be given to the collection of process data for totally unrelated chemical and pyro-processing industries.

The selection of dust collecting equipment for pyro-processing industry is not a simple matter of asking the equipment manufacturer to select and erect the newest 1969 model and expecting it to operate satisfactorily.

Survey data has been compiled to show existing conditions for various cement plants operating throughout the United States. Data has been obtained from (1) H.E.W., U.S.P.H.S. Publication #999-AP-17, "Atmospheric Emissions From The Manufacture Of Portland Cement", and (2) members of the Technical Subcommittee, Cement Environmental Matters, American Mining Congress.

Average operating experience conservatively indicates approximately 10% of the total weight of the materials introduced in the cement manufacturing process at the feed end of the rotary cement kiln leaves the kiln and becomes gas-borne.

To appreciate the magnitude of this problem and emission control efficiencies requied, let us consider the previously mentioned survey data from 50 reports.

(V-17)

If we plot the average emission rate of 200 pounds per hour versus 115,000 pounds per hour process weight, we establish a point of reference.

We may then develop an equation for defining a relationship between emission and process weight. The equation developed is $E = 26.5\ P^{0.5}$ and the values for emission are based on a related amount of process weight.

If we consider the average condition of 3,870 barrels per day of clinker production with an estimated process weight of 115,000 pounds per hour and an emission rate of 200 pounds per hour, a collecting efficiency of 98.2% is indicated.

To comply with the Bay Area Code emission limitation of about 45 pounds per hour, the required efficiency would be 99.6%. The Los Angeles Code limitation of 400 pounds per hour would require an efficiency of 99.65%.

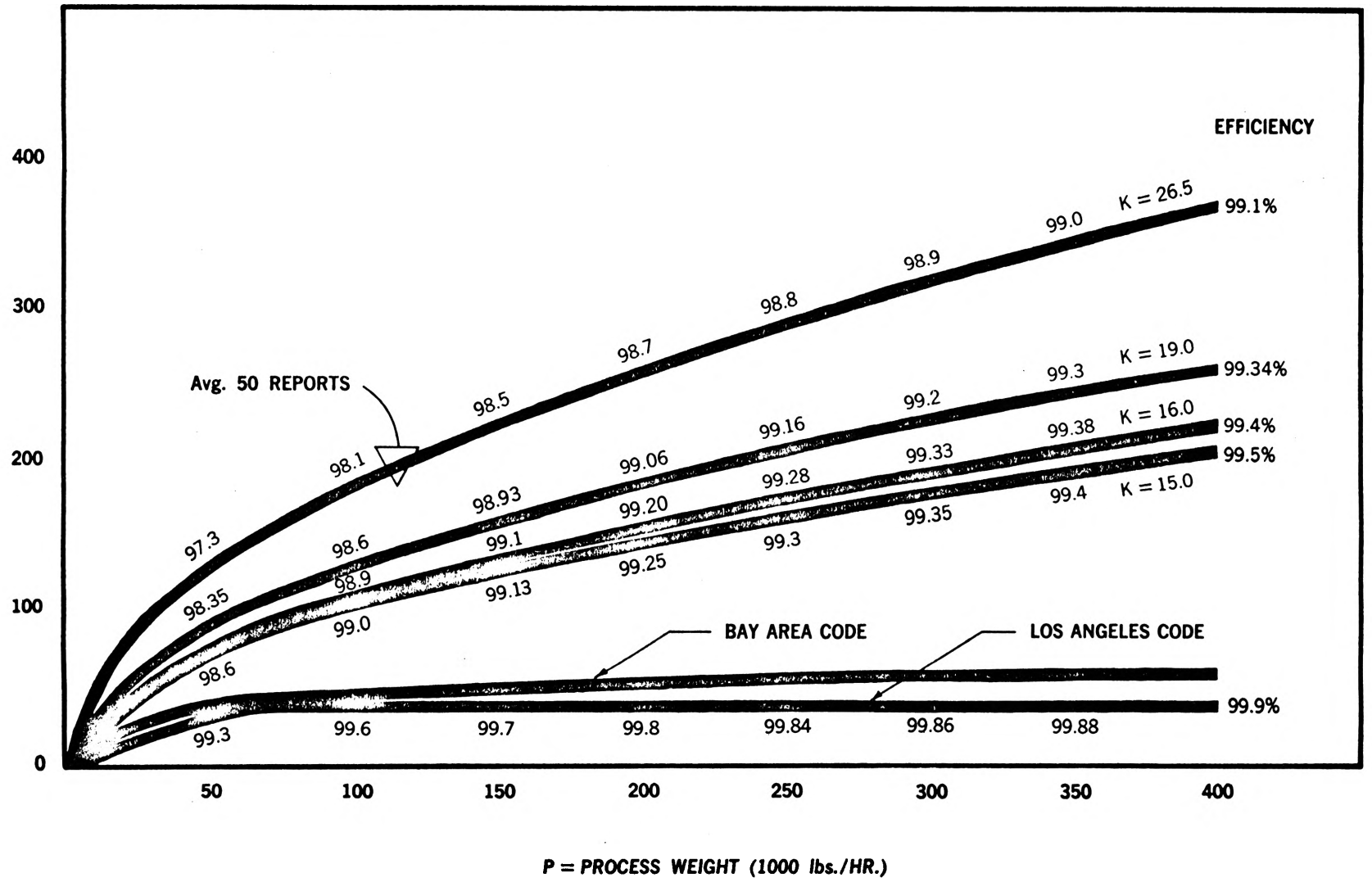
This means it would be necessary to modify the average existing collector to further reduce its exit gas dust loading by 80%. In some instances, this might be achieved by complete rehabilitation, but complete replacement would more often be required. In some instances, complete replacement by the higher efficiency, larger collector may be physically impossible.

The Clean Air Act of 1967 recognizes the needs for establishing cost-benefit relationships as well as the need for ambient air quality control by means which are "technically feasible and economically reasonable".

It is obvious from this slide that consideration of these factors is particularly important when considering the efficiencies

(V-17)

# PROCESS WEIGHT EFFICIENCIES



required to achieve compliance under any of the control curves represented.

For example, the required efficiency for compliance under curve K = 16 or E = 16.0 $P^{0.5}$ ranges from approximately 98.5% at 50,000 pounds per hour to 99.4% at 400,000 pounds per hour, for the average 10% loss of kiln product. At 15% dust loss, 99.7% efficiency is required at 400,000 pounds per hour. These data are typical for many existing kiln operating conditions.

Compliance under the Bay Area Code for the same process weight range would be from about 99.3% - 99.9%.

When considering the "Technically feasible, economically reasonable", cost-benefits aspects of pollution control legislation, the logic of the universal application of a specific process weight regulation is questionable.

For example, five small kilns each operating at a process weight of 30 tons per hour would be permitted a total emission of 200 pounds per hour, while one kiln operating at 150 tons per hour would be permitted an emission of only 53 pounds per hour - 1/4 the emission for the same process weight.

It is not "technically feasible, economically reasonable" nor does it seem logical to force industry into the position of installing a multiple number of small units rather than one large unit simply as a means of regulation compliance with no increased air pollution control benefits.

(V-18) (not included in paper)

The Ringelmann Chart used to regulate particulate emission or for Equivalent Opacity control of visibility is also an enforcement tool subject to question when related to cement kiln stack measurements.

The wet or dry process kiln stack plume are conditions far removed from the originally intended use of the Ringelmann Chart - black smoke.

This slide shows the appearance of a wet process stack plume with the sun at the back of the observer - as prescribed for Ringelmann Chart use. The plume was recorded to be a Ringelmann 0.25.

(V-19) (not included in paper)

This slide shows the same plume viewed by the observer as he faced the sun. In this instance, the plume was recorded as a Ringelmann 4.

Obviously, the position of the observer with respect to sun location is critical.

## Conclusion

Long before air pollution control regulations were a factor, the cement industry in general recognized its responsibility for air pollution emission control.

Dust collection equipment representing the latest in control technology available at the time has been installed at substantial cost.

Technology has improved to the extent that, in some instances, emission control improvements can and should be made within our industry.

The cost of improved emission control will be substantial. The investment required by multi-plant companies with plants located in many different states will be tremendous; and remember there will be no financial return resulting from this investment.

The job will be done - the money will be spent, but proper emphasis should now be placed on the "technically feasible, economically reasonable, practically enforceable" air pollution control regulation and the logical priorities for achieving the same.

Obviously, the need for improved air quality will not dictate identical needs or priorities for every geographical location in this country.

The cement industry has offered its technical assistance to those engaged in the important task of developing logical air pollution control regulations.

Only through the cooperative efforts of the control agency, the public and industry will we be able to achieve the goals of desirable air quality levels.

In his preface to the recently issued H.E.W. publications on "Control Techniques for Sulphur Oxide and Particulate Air Pollutants", Dr. John T. Middleton stated: "The control of air pollutant emissions is a complex problem because of the variety of sources and source characteristics. Technical factors frequently make necessary the use of different control procedures for different types of sources. Many techniques are still in the developmental stage, and prudent control strategy may call for the use of interim methods until these techniques are perfected. Thus, we can expect that we will continue to improve, refine, and periodically revise the control technique information so that it will continue to reflect the most up-to-date knowledge available."

All those concerned with air quality control would do well to seriously consider the implication of Dr. Middleton's words and use

caution in the universal application of pollution control concepts logically employed in some instances, but illogically applicable in other instances.

## COMMENTS

QUESTION: One thing that occurred to me is that obviously the Rengleman chart was not intended for use of checking cement plants. Have you some recommendations as to what you think would be a preferable means of checking cement plants for enforcement against air pollution?

ANSWER (Mr. Hailstone): I personally prefer a process concept for the simplicity involved but the important aspect then becomes the numbers that you use, or the equation that you use for developing the curve of the data, or the table for allowable admissions. The use of the Rengleman chart concept is beased on visibility control of the mission which is becoming an increasingly imporatnt factor, I don't have as firm a conviction as to what the substitute measures should be.

QUESTION: How do the Texas regulations affect the cement industry?

ANSWER: Texas regulation based on an ambulant air level quality is a consideration or concept which as somebody said earlier this morning, we would like to think is a more logical approach to control. Now as I understand it, the Texas existant regulations are based upon what are called Sutton's equation. There are a couple of different ways to check and see whether they are within compliance of existing Texas regulations. One is to take up-wind and down-wind measurements of particulates and micrograms per cubic meter at ground level. The other is to measure you back discharge and see according to the sub equation that you would not exceed a certain level in micrograms per cubic meter at the point of concern. That is essentially what the Texas regulation consists of today.